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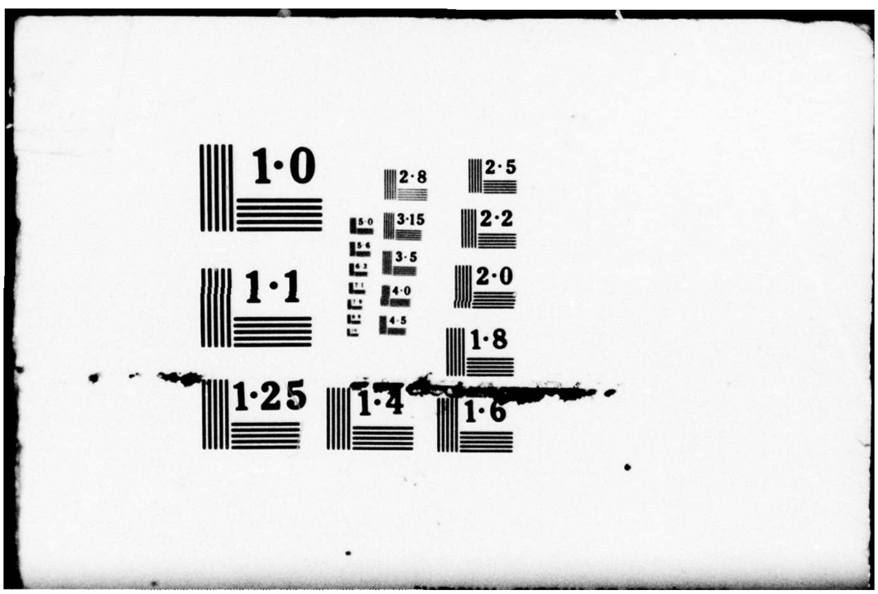
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DESTROYER ENGINEERED OPERATING CYCLE (DDEOC)

System Maintenance Analysis

DDG-37 CLASS

EMERGENCY DIESEL GENERATING SYSTEM

SMA 37-208-312

REVIEW OF EXPERIENCE

August 1978

Prepared for
Director, Escort and Cruiser
Ship Logistic Division
Naval Sea Systems Command
Washington, D. C.
under Contract N00024-78-C-4062

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DESTROYER ENGINEERED OPERATING CYCLE (DDEOC), SYSTEM MAINTENANCE ANALYSIS DDG-37 CLASS, EMERGENCY DIESEL GENERATING SYSTEM SMA 37-208-312,

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by

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FOREWORD

This report, the Review of Experience, documents the historical maintenance experience for the DDG-37 Class Emergency Diesel Generating System, presents an analysis of the problems encountered, and recommends actions to improve system material condition. It has been developed for NAVSEA 934X, the sponsor of the Destroyer Engineered Operating Cycle (DDEOC) Program, under Contract N00024-78-C-4062.

SUMMARY

The goal of the Destroyer Engineered Operating Cycle ~~(DDEOC)~~ Program is to effect an early improvement in the material condition of ships, at an acceptable cost, while maintaining or increasing their operational availability during an extended operating cycle. In support of this goal, System Maintenance Analyses (SMAs) are being conducted for selected systems ~~and subsystems~~ of designated surface combatants. The principal element of an SMA is the Review of Experience (ROE). This report documents the ROE for the DDG-37 Class Emergency Diesel Generating System.

The ROE is an analysis of existing and anticipated problems that affect the operational performance or maintenance program of a ship system. The ROE report serves as a vehicle for assessment of the significance and consequences of identified problems. It also presents specific recommendations and a system maintenance policy for preventing or reducing the impact of the occurrence of a maintenance problem while improving material condition and maintaining or increasing system availability throughout an extended ship operating cycle.

The Emergency Diesel Generating System ROE included an analysis of all available maintenance data sources. The documented maintenance experience of the system was reviewed through analysis of Maintenance Data System (MDS) data, Casualty Reports (CASREPs), and system overhaul records. Initial findings from these sources were correlated with Planned Maintenance System (PMS) requirements, system alterations, and system technical manuals to identify maintenance problems. Ship surveys were conducted and discussions were held with appropriate technical codes in order to validate identified problem areas, identify undocumented maintenance problems, and determine the status of current and planned actions affecting the Emergency Diesel Generating System. All findings were evaluated, and appropriate conclusions were developed. Recommendations were then formulated to implement existing and newly defined corrective actions to minimize the occurrence of identified problems and their effect on the extended operating cycle.

ROE

The major conclusions resulting from the Review of Experience for the Emergency Diesel Generating System are summarized as follows:

include

- Although a large corrective maintenance burden was reported against the Emergency Diesel Generating System, the burden does not represent any repetitive maintenance problems. (cont on p II)

(cont fr p v)

- Routine overhauls of Emergency Diesel Generating System components are not necessary and will not be required during ~~B~~aseline ~~O~~verhaul nor the follow-on ~~R~~egular ~~O~~verhaul, except as required by inspection; and

- The current maintenance strategy, a combination of scheduled and "on-condition" maintenance requirements and required inspections, is adequate to maintain the Emergency Diesel Generating System throughout an extended operating cycle.

- It was determined by this analysis that a Class B overhaul of the Woodward governor, as specified by the DDEOC Repair Requirements for Baseline Overhaul, is not justified. Any necessary governor repairs will be identified during the pre-Baseline Overhaul diesel inspection.

Reliable operation of the Emergency Diesel Generating System can be expected during the Engineered Operating Cycle if several recommended changes are performed in the following areas:

- Baseline Overhaul (BOH) Requirements
- Follow-On ROH Requirements
- Planned Maintenance System Changes

Table S-1 summarizes all recommendations resulting from this Review of Experience. No recommendations regarding intra-cycle maintenance, reliability and maintainability improvements, integrated logistics support improvements, or IMA and depot-level improvements resulted from this analysis.

Table S-1. SUMMARY OF DDG-37 CLASS EMERGENCY DIESEL GENERATING SYSTEM ROE RECOMMENDATIONS	
Component	**Recommendation**
Baseline and Follow-on Regular Overhaul Requirements	
Emergency Diesel Engines	A certified diesel inspector should inspect the engines in accordance with COMNAVSURFLANTINST 9000.1 or COMNAVSURFPACINST 4700.1 (as applicable) to determine the necessary repairs. If not already done, implement the MEASURE program (the automated measuring device calibration management program). The fuel injectors should be removed, sent to an IMA, tested for popping pressure and spray pattern, and re-installed or replaced as necessary.
Generator	Make repairs as shown to be necessary by a POT&I. As a minimum, clean the commutators and slip rings and clean and adjust the brush rigging.
Salt Water Booster Pumps	Repair the pumps as shown to be necessary by each ship's CSMP and the cyclic PMS inspection.
Salt Water Booster Pump Motors	Repair the motors as shown to be necessary by each ship's CSMP and POT&I results.
PMS Changes	
Emergency Diesel Engines	A note should be added to the MIPs to have the ships that have no fuel injector tester installed send the fuel injector nozzles to an IMA for test according to the schedule specified for the test MRC.
No recommendations regarding intra-cycle maintenance, reliability and maintainability improvements, or IMA and depot-level improvements resulted from the analysis.	

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

In support of the Destroyer Engineered Operating Cycle (DDEOC) Program, sponsored by NAVSEA 934X, System Maintenance Analyses (SMAs) are being conducted on selected systems and subsystems of program-designated surface combatants. The principal element of an SMA is the Review of Experience (ROE). This report documents the ROE for the DDG-37 Class Emergency Diesel Generating System, which was selected for analysis because equipments of this system are on the DDG-37 Class Maintenance Critical Equipment List.

1.2 PURPOSE AND SCOPE

The ROE is an analysis of existing and anticipated problems that affect the operational performance or maintenance program of a ship system. The ROE report serves as a vehicle for assessing the significance and consequences of identified problems. The report also recommends specific actions and a system maintenance policy directed toward preventing or reducing the impact of the occurrence of a maintenance problem while improving material condition and maintaining or increasing system availability throughout an extended ship operating cycle.

The analysis documented herein is specifically applicable to the Emergency Diesel Generating System of the DDG-37 Class. Only those system components that had been installed or were onboard ship as of 30 September 1977 were considered. The analysis used all available documented data sources from which system maintenance problems could be identified and studied. These included Maintenance Data System (MDS) data, Casualty Reports (CASREPs), and system overhaul records, in addition to Planned Maintenance System (PMS) requirements data, system alteration documentation, and system technical manuals. Sources of undocumented data employed in this analysis included discussions with Ship's Force and other cognizant technical personnel.

1.3 SYSTEM FUNCTION AND BOUNDARIES

Each DDG-37 Class ship is fitted with two emergency diesel generating sets. Each is composed of a 7-cylinder Fairbanks-Morse Model 38F5-1/4 opposed piston diesel engine, a 300-kW General Electric ac generator, and all accessories necessary to provide the engine with fuel, intake air, and coolant. Speed of each engine is regulated by a Woodward Governor Company Model UG-8 hydraulic governor. These emergency diesel generator sets are designed to supply emergency power in the event of Ship's Service Turbine Generator failure and, therefore, have an automatic start capability.

Appendix A provides a list of system components included in the analysis documented by this report.

1.4 REPORT FORMAT

The remaining chapters of this report describe the analysis approach utilized (Chapter Two), briefly define significant system maintenance problems encountered and discuss potential problem solutions (Chapter Three), and summarize conclusions and recommendations derived from the analysis (Chapter Four). Specific analyses and evaluations supporting the results of this effort are included as appendixes to this report. A selected list of references precedes the appendixes.

CHAPTER TWO

APPROACH

Primary data sources used in performing the ROE for the Emergency Diesel Generating System are identified in Section 1.2. The data were used to identify, define, and analyze maintenance problems that will significantly affect the system's maintenance program. A recommended course of action relative to the maintenance program was formulated on the basis of the analysis results.

The analysis began at the component level at which Allowance Parts List (APL) numbers are assigned. It comprised the following major steps, as described in Sections 2.1 through 2.3:

- Compiling relevant documented and undocumented maintenance history data
- Analyzing these data to identify and define maintenance problems expected to have a significant effect on maintenance of the system
- Recommending a specific course of action for the solution of system maintenance problems

2.1 DATA COMPILATION

The analysis began with the compilation of comprehensive data on the maintenance history of the system. The data file generated consisted of three key elements: an MDS data bank, a CASREP narrative summary, and a system overhaul experience summary. A library of appropriate technical manuals, bulletins, and related documents was also assembled. The MDS data bank was compiled by examination of all MDS data reported for the DDG-37 Class from 1 January 1970 through 30 September 1977. Overhaul information was obtained from authorized Ship Alteration and Repair Packages (SARPs) for the DDG-37 Class.

2.2 MAINTENANCE PROBLEM DEFINITION

Potential maintenance problems associated with the systems and their components were identified by screening data obtained from the above-described sources as well as from ship surveys, discussions with Navy technical personnel, and, when appropriate, NAVSEA special-interest programs.

MDS data constituted the initial and primary source of information screened. The resulting data base included all part and labor records, as well as narrative material, describing maintenance actions reported against system components. Maintenance actions are represented by Job Control Numbers (JCN). The purpose of the first step in the screening process was to identify the maintenance actions that had been reported against components of the system under investigation.

Computer-assisted analysis quantified the man-hour and part-expenditure burdens incurred for each component, not only for the selected components individually, but also, as appropriate, for each generic class of components. Individual components or component classes that had contributed significantly to the system's maintenance burden were selected for analysis if they had generated a significant number of CASREPs or if other sources of information (e.g., ship surveys or overhaul experience) disclosed significant concern regarding maintenance problems or the maintenance programs for the components.

Detailed analysis of the selected components was directed toward defining each maintenance problem in terms of several specific factors: the effect of the problem on the component and system, the interval between occurrences of the problem, the redundancy of the affected component within the system, the criticality of the component to the system, the resources required to perform the maintenance necessary to correct the problem, and the expected component or system downtime.

2.3 ANALYSIS OF COMPONENT MAINTENANCE PROBLEMS AND DEFINITION OF SOLUTIONS

Once the component maintenance problems and their causes were identified, solutions were sought by examining each problem in relation to the extent to which it is recognized and its susceptibility to established types of corrective action. These analysis criteria are expressed in the following questions:

- Is the problem known to the Navy technical community and has a solution been proposed or established?
- Will a design change reduce or eliminate the problem?
- Is the problem PMS-related? Can the problem be reduced or eliminated by changes to PMS? (These changes might include adding or deleting requirements, changing requirement frequency, or developing material condition assessment tests and procedures.)
- Can the problem be reduced or eliminated by improving the Ship's Force, Intermediate Maintenance Activity (IMA), or depot-level capabilities?
- Can the problem be reduced or eliminated by periodically performing restorative maintenance? Should this be accomplished at a Selected Restricted Availability (SRA) by Ship's Force, IMA, or depot-level facilities?

* Is the run-to-failure concept a viable maintenance strategy for the associated equipment?

An affirmative answer to any question resulted in analysis of the effects of the solution and in an estimate, when possible, of the cost to implement the solution. A negative answer prompted the analyst to go to the next question. After all the questions were answered, the alternative near-term and long-term solutions were evaluated and the most acceptable alternatives defined and documented as recommendations. "Near-term" recommended solutions, as used in this report, are those that should be, and are likely to be, accomplished before completion of the initial DDG-37 Class Baseline Overhaul (BOH). "Long-term" recommended solutions are those that are not likely to be accomplished until some or all of the DDG-37 Class BOHs have been completed.

The historical overhaul experience for all installations of each selected component was then correlated with the recommended problem solutions. An evaluation was made to establish the BOH requirements for each selected component.

CHAPTER THREE

RESULTS

3.1 OVERVIEW

This chapter presents the results of the Review of Experience for the DDG-37 Class Emergency Diesel Generating System. Data screening resulted in the identification of six system components as the major contributors to the maintenance burden (see Table 3-1). Twenty-seven parts within these six components were identified as items requiring detailed analysis (see Table 3-2).

CASREP analysis supported the MDS data screening performed in defining repetitive problems and significant maintenance actions. Appendix B summarizes the CASREPs submitted against the components of the Emergency Diesel Generating System, shows the percentage of the total number of CASREPs attributable to each component, and indicates the types of failures experienced by those components. System maintenance problems, recommended solutions, and the strategy by which the system should be maintained are discussed in the following sections.

3.2 DIESEL ENGINES

Each DDG-37 Class ship has two Fairbanks-Morse Model 38F5-1/4, opposed piston, two-cycle, diesel engines driving two 300-kW General Electric ac generators. The engines for this class are supported by APLs 665360181, 665360182, and 665360207. They are started by electric motors that are supplied with electricity from storage batteries. The operating speed of each engine is regulated by a Woodward UG-8 governor, and the fuel oil is supplied by an American Bosch fuel injection system. Each engine-generator unit, with accessories, is mounted in an operating compartment separate from other shipboard equipment. One engine-generator unit supplies power to the forward end of the ship; the other unit supplies the aft end of the ship. According to ship personnel, both units accrue about the same amount of operating time.

A review of the MDS Data showed that the diesel engines experienced a maintenance burden that totaled 395 JCNs, 4,908 man-hours (3,021 man-hours by Ship's Force and 1,887 man-hours by IMAs), and $29,324 in part replacement costs. Each engine averaged 41.7 maintenance man-hours per

Table 3-1. MAINTENANCE BURDEN SUMMARY FOR DDG-37 CLASS EMERGENCY DIESEL GENERATOR SYSTEM COMPONENTS

APL	Nomenclature	Applicable Ships	Components per Ship	Total Component Population	Total Ship Operating Time (Ship-Years)	Ships Reported	JCNs	Ship's Force Man-Hours	IMA Man-Hours	Total Man-Hours	Parts Cost (Dollars)	Average Man-Hours/ Component Operating Year	Average Man-Hours/ JCN
665360181 665360182 665360207	Diesel Engines (includes governors, fuel injectors, fuel injection pumps, attached fuel pumps, starter, lube oil pumps, and filters)	10	2	20	58.8	10	395	3,021	1,887	4,908	29,324	41.7	12.4
016060106	Salt Water Booster Pump	10	1	10	58.8	10	33	283	249	532	4,667	9.0	16.1
016060108	Salt Water Booster Pump	10	1	10	58.8	7	22	121	53	174	2,421	3.0	7.9
174750604	Salt Water Booster Pump Motor	10	1	10	58.8	7	15	108	105	213	202	3.6	14.2
17475058[illegible]	Salt Water Booster Pump Motor	10	1	10	58.8	3	3	10	80	90	78	1.5	30.0
162500162	440 V, 60 Hz Generator	10	2	20	58.8	10	37	205	103	308	973	2.6	8.3
	Totals Reported For Selected APLs						505	3,748	2,477	6,225	37,665	106*	12.3
	Totals Reported For All APLs						643	4,347	2,764	7,111	47,602	121*	11.0
	Percent of Reported Totals Accounted For By Selected APLs						78	86	90	88	79	–	–

*System manhours per ship operating year.

Table 3-2. PARTS USAGE DATA FOR SELECTED COMPONENTS OF THE DDG-37 CLASS EMERGENCY DIESEL GENERATING SYSTEM

Part Identification: National Stock Number (NSN)	Part Identification: Nomenclature	Cost per Unit (Dollars)	Quantity per Component	Total Part Population	Number Replaced	Ratio (×100) of Parts Replaced to Total Population	Number of JCNs Reported	Number of Ships Reported
Diesel Engines (APLs 665360181, 665360182, and 665360207)								
9G-5977-00-090-2765	Starter Brush	5.07	8	160	18	11	3	3
9C-2916-00-218-6579	Injector Nozzle	10.71	7	140	130	93	17	8
1H-5120-00-240-9771	Tool Assy. Lnr.	55.00	1	10	3	30	3	3
9C-2815-00-277-2919	Piston Compression Ring	1.25	42	840	60	7	6	3
9C-2815-00-287-1912 9C-2940-00-287-1931	Filters	1.26 6.47	2	60	181	302	41	10
9C-2815-00-338-4832	Valve-Indicator	52.87	7	140	20	14	7	5
9C-2815-00-343-2658	Bearing Half	16.47	32	640	50	8	3	3
9Z-3120-00-343-9819	Conrod Bearing	11.55	28	560	31	5	3	3
9C-2910-00-364-2951	Spindle w/seat	1.40	7	140	29	21	4	4
9C-2815-00-388-2709	Ring-Piston (Oil Drain)	4.26	28	560	80	14	8	3
9C-2815-00-388-2710	Ring-Piston (Oil Spray)	9.48	14	280	45	16	7	3
9C-2910-00-609-8790	Seat, Spr Upper	0.50	7	140	18	13	3	3
9C-2910-00-654-9021	Tube Assy-Injector	51.55	7	140	6	4	6	4
1HS0000-LL-CG9-7309	Auxiliary Drive Assembly	>1000	1	20	1	5	1	1
Generator (APL 162500162)								
9G-5977-00-239-4121	Brushes	2.11	4	80	47	59	6	5
Salt Water Booster Pump (APL 016060106)								
9C-4320-00-393-3486	Shaft Sleeve	36.61	1	10	7	70	7	7
9C-4320-00-595-2779	Casing Wearing Ring	16.12	2	20	12	60	6	4
9Z-5310-00-595-6096	Flat Washer	.87	1	10	3	30	3	3
9Z-5310-00-141-1768	Nut-SLKG CAP	4.59	1	10	3	30	3	3
9C-4320-00-993-7374	IMP Wearing Ring	39.83	2	20	10	50	5	4
Salt Water Booster Pump (APL 016060108)								
9Z-5310-00-141-1763	Nut SLKG Cap	3.87	1	10	5	50	3	3
9C-4320-00-146-4634	Ring-BUP	20.12	1	10	4	40	4	4
9Z-3120-00-294-0855	Thrust Bushing	2.07	1	10	6	60	6	5
1HM4320-00-393-3513	Shaft Sleeve	33.00	1	10	9	90	9	7
9C-4320-00-554-8105	Casing Wearing Ring	31.24	1	10	8	80	6	5
Salt Water Booster Pump Motor (APL 174750587)								
9Z-3110-00-156-5048 9Z-3110-00-193-2085 9Z-3110-00-227-2247 9Z-3110-00-727-0620	Motor Bearings	11.75 - 20.28	2	20	5	25	4	-
Salt Water Booster Pump Motor (APL 174750604)								
9Z-3110-00-153-8255 9Z-3110-00-193-1975 9Z-3110-00-193-2418 9Z-3110-00-198-2419 9Z-3110-00-227-2247 9Z-3110-00-727-0620 1H-3110-00-991-0940	Motor Bearings	2.93 - 22.50	2	20	26	130	16	-

operating year and 12.4 maintenance man-hours per JCN. Fifteen CASREPs were submitted against the engines, for an average of 0.24 CASREPs per engine per ship operating year. The DDG-37 Class Repair Profile listed no repetitive repairs that have been accomplished on the engines during Regular Overhauls.

The MDS transaction narratives indicated many different failure modes as causes for the reported maintenance burden. Table 3-3 lists the major sources of the engine maintenance burden and identifies the major failure modes experienced by the engines. Of the maintenance actions and failure modes listed in the table, only maintenance of the fuel injector nozzles, the measuring devices (pressure gages, thermometers, pyrometers, and tachometers), and the fuel supply pumps and major engine repairs were considered to be significant. Those actions that were the result of PMS or other required inspections, or whose failure modes were not reported in the data were not considered significant. The remaining failure modes were not considered significant for one or both of the following reasons:

- No CASREPs were submitted.
- The quantity of JCNs submitted against an individual failure mode was less than 12 (the equivalent of one JCN every five ship operating years).

The significant sources are discussed in the following paragraphs.

3.2.1 Fuel Injector Nozzles

Each diesel engine has seven fuel injection nozzles installed to spray fuel into the engine. The MDS part usage data indicated that 130 nozzles were used during the data period, corresponding to about 93 percent of the nozzle population. Of the diesel engine failures reported in the MDS narratives, failed fuel injection nozzles contributed the largest number of man-hours to the diesel engine maintenance burden (see Table 3-3). The nozzles required 39 JCNs, 527 Ship's Force man-hours, 310 IMA man-hours, and $3290 in part replacement costs. The average man-hour burden per engine per operating year for fuel injection nozzles was about seven man-hours, which is low when compared to other systems. Nine ships reported maintenance against the nozzles. The average man-hour burden per JCN was about 22 man-hours, which seems high. However, a review of the part usage data showed that the nozzles were usually replaced in sets of seven, which makes this burden seem reasonable. Three CASREPs were submitted against the nozzles for leaks. The reported burden, nozzle usage, and CASREPs suggested the fuel injection nozzles would have been a maintenance problem to Ship's Force. During discussions with Ship's Force personnel, however, it was found that fuel injection nozzles have not been a maintenance problem. The discussions indicated additionally that at least some of the nozzles were ordered as spares to ensure that the diesel engines would not be out of commission for lack of parts. However, a problem with fuel injection nozzle maintenance was identified during the discussions.

Table 3-3. MAJOR SOURCES OF DIESEL ENGINE BURDEN, RANKED BY MAN-HOURS

Failure Mode or Maintenance Action	Number of JCNs	Man-Hours			Number of Ships Reported	Part Costs	Manhours Per JCN	Engine Operating Years Per JCN *	Number of CASREPs
		Ship's Forces	IMA	Total					
Fuel Injector Nozzles leak, need test, or were replaced.	39	527	310	837	9	3290	21.5	3.0	3
Measuring devices need repair, replacement, or calibration.	92	462	312	774	10	4148	8.4	1.3	3
Major engine repairs.	13	484	181	665	7	2340	51.2	9.0	4
Failure mode not reported.	37	308	166	474	8	898	12.8	3.2	0
Fuel supply pump problems.	13	287	164	451	6	5650	34.6	9.0	3
Diesel inspection (not PMS).	10	269	155	424	7	0	42.4	11.8	0
Deferred PMS.	60	277	105	382	6	981	6.4	2.0	0
Governor - tests, cleaning, or fails to maintain speed.	8	80	138	218	5	67	27.2	14.7	0
Relief valves - tests, were repaired or were replaced.	9	43	90	133	3	0	14.8	13.1	0
Starting batteries were filled or replaced.	7	28	60	88	5	1801	12.6	16.8	0
Filter replacements.	43	46	38	84	10	1624	2.0	2.7	0
Starter motor burn-out or part replacements.	8	12	0	12	4	319	1.5	14.7	2
GRAND TOTALS	339	2823	1719	4542	-	21,118	13.4	0.3	15
Percentage of Diesel Engine Totals	85.8	93.4	91.1	92.5	-	72.0	-	-	100.0
Percentage of System Totals	52.7	64.9	62.2	63.8	-	44.4	-	-	78.9

$$\text{* Engine Operating Years/JCN} = \frac{\text{58.8 Ship Operating Years} \times \text{2 Engines/Ship}}{\text{Number of JCNs Submitted}}$$

The PMS for the diesel engines [Maintenance Index Pages (MIPs) A-2/114-87 and A-2/078-27] specifies tests of the fuel injection nozzles for popping pressure and spray pattern [Maintenance Requirement Cards (MRCs) 84-2EWA-Y and B3-1SYZ-Y]. Both MRCs require that the ships have a fuel injector tester that allows accomplishment of the maintenance requirement. Personnel on the two DDG-37 Class ships visited stated that they did not have the tester. Maintenance personnel on both ships stated that the nozzles must be sent to a tender or SIMA (Shore-based Intermediate Maintenance Activity) for testing. The MRCs are supposed to be accomplished annually, or when directed as a result of lube oil analysis (the lube oil analysis lab would direct that the nozzles be tested only when the analysis results indicated excessive fuel dilution of the lube oil). However, without the tester the test cannot be performed, and leaking nozzles cannot be identified. Therefore, to limit the fuel dilution of the lube oil, Ship's Force has replaced fuel injection nozzles in sets. A review of MDS data confirmed that to be the practice.

Although the burden reported against the fuel injection nozzles was the highest reported against the diesel engine, Ship's Force does not consider the nozzles to be a maintenance problem because replacement of the nozzles is within their capability and because fuel dilution of the lube oil, as indicated by lube oil analysis, has not been a significant problem. It is possible that the number of fuel injection nozzle replacements would be reduced if the tester were on all the DDG-37 Class ships. One set of nozzles is normally stocked on board, so there would be little downtime awaiting parts if a failure should occur. Because each of the two diesel generators installed on each DDG-37 Class ship serves a separate portion of the ship, the fuel injection nozzles assume major importance to the system in establishing the system's capability to provide emergency power. In view of the importance of proper nozzle condition and performance, the fuel injection nozzles should be removed, sent to an IMA, tested for proper spray pattern and popping pressure, and replaced as necessary or reinstalled during the Baseline Overhaul and the follow-on Regular Overhaul. Because only three CASREPs were submitted against the nozzles, it is concluded that failures to the nozzles did not repetitively and seriously degrade system and ship capabilities. In addition, the low reported fuel injection nozzle man-hour burden per engine per operating year indicates that the fuel injection nozzles have not been a significant drain on ship's resources. It is concluded, therefore, that scheduled replacement of the nozzles is not necessary.

The Type Commander's (TYCOM) Coordinated Shipboard Allowance List (COSAL) indicated (see Appendix A, Table A-1) that six of the ten DDG-37 Class ships have the fuel injector tester (APL 462030001) installed. According to the TYCOM COSAL, hulls DDG-38, 39, and 43 have two testers each, while hulls DDG-37, 40, and 45 have one tester each. It could not be confirmed whether or not those ships actually have the tester installed. This tester can be useful in determining the condition of fuel injection nozzles and identifying leaking nozzles. However, with little evidence that leaking nozzles or improper spray patterns are maintenance problems, it seems unlikely that the tester is actually needed. The Navy Management Data List

(NMDL) currently lists the tester at a replacement cost of $710. To install the tester on the four ships that do not have it would cost $2840, which is about 86 percent of the total reported part replacement cost experienced during the data period. Accordingly, in view of the few reported fuel injection nozzle problems that could be identified through the use of tester, the installation costs of the testers, and the established capability of IMAs to test fuel injection nozzles, it is concluded that installation of the testers on hulls DDG-41, 42, 44, and 46 is not warranted. With spare nozzles stocked onboard ship, suspect nozzles can be replaced and held aboard ship until testing can be accomplished by an IMA. Therefore, for those ships with a tester onboard, Ship's Force personnel should perform the nozzle testing according to the MRC. For those ships without a tester, the nozzles should be sent to an IMA for testing annually, or when directed as a result of lube oil analysis. This can be accomplished by adding to the MIPs a note that directs ships without the tester to send the nozzles to an IMA for testing.

3.2.2 Measuring Devices

Table 3-3 shows that the various measuring devices had the second highest reported man-hour burden reported against the diesel engines. A total of 92 JCNs, 462 Ship's Force man-hours, 312 IMA man-hours, and $4148 in part replacement costs were reported against measuring devices. ("Measuring Devices" include pressure gages, vacuum gages, thermometers, pyrometers, and tachometers.) A review of the MDS narratives showed that the majority of this burden (716 man-hours or 92 percent) was the result of calibrating the devices in accordance with PMS. There were 68 JCNs in which calibration was reported, for an average of 10.5 man-hours per JCN for calibration. A further review of the narratives showed that a total of 24 man-hours was expended in replacing measuring devices, and 34 man-hours were expended in repairing measuring devices. From these data, it is concluded that corrective maintenance of measuring devices has not been a maintenance problem, but that the calibration requirements specified in PMS have resulted in significant man-hour expenditures.

A calibration management program has been established at SURFLANT to aid Ship's Force in identifying the gages, thermometers, electronic test equipment, etc., that require calibration at any given time. This program, called MEASURE, supplies each ship with pre-printed multi-part forms with the name, location, APL, and newly established serial number of the particular gages and similar devices that have periodic calibration requirements. Ship's Force must engrave the serial numbers on the devices and return the forms to SURFLANT. In return, SURFLANT supplies the ship with a computer print-out, by serial number, of the devices that need calibration, where the device is located, and when the device must be recalibrated. In this way, Ship's Force is relieved of the requirement to identify, by visual inspection of the calibration sticker, which devices require calibration. Ship's Force will be required only to review the printouts and assign crew members to remove the appropriate devices so that they can be sent to the calibration facility at the SIMA. It is anticipated that the MEASURE program will improve the timeliness of calibration and reduce Ship's Force work load. The MEASURE program should be implemented on all DDG-37 Class ships before or during Baseline Overhaul.

3.2.3 Major Engine Repairs

Major engine repairs were the third highest contributor to the diesel engine maintenance burden (see Table 3-3). Major engine repairs are defined as those repairs that require disassembly of the engine and include repairs to pistons, connecting rods, the crankshafts, the auxiliary drive, etc. A total of 13 JCNs, 484 Ship's Force man-hours, 181 IMA man-hours, and $2340 in part replacement costs were reported against the diesel engines. Seven of ten ships reported major engine maintenance; nine CASREPs were submitted by six ships. Two CASREPs were submitted for worn or broken piston rings, two for a broken fuel pump drive gear, two for an inoperative starter motor, one for loose main bearings, one for a sheared fuel pump drive shaft, and one for an inoperative fresh water pump. These data show no repetitive failures that significantly reduced diesel engine capabilities. A review of the MDS narratives revealed that the most repetitive action was repair or replacement of pistons or piston rings, which occurred in four JCNs on four ships. The other major repairs identified engine overheating or required replacement of main bearings, replacing the lower crankshaft, etc. These repairs occurred on several different ships and are not considered significant. It is concluded that no repetitive repairs were performed on the diesel engines.

The DDG-37 Class departure reports were reviewed to identify the maintenance that occurred during ROHs, COHs, and AAW (Anti-Air Warfare) conversions. Except for the AAW conversions, little maintenance was performed on the *entire* Emergency Diesel Generating System during ROHs and COHs. During seven AAW conversions, an average of about 407 man-days was expended on the emergency diesel generator (includes the engines and generators, but not the salt water booster pumps, the pump motors, or the operating cables). DDG-37 Class Type Desk personnel reported that the emergency diesel generators were overhauled during the AAW conversions. Judging by the small number of man-days reported during ROHs and COHs, no other emergency diesel generator overhauls were accomplished. Because of the limited number of repetitive repairs and the few overhauls that have been performed, it is concluded that the diesel engines have operated reliably throughout the data period; because of their reliable operation, routine overhaul of the diesel engines is not warranted for Baseline Overhaul. Although the diesel engines perform a critical function aboard ship, maintenance experience indicates that major engine failures have not been repetitive and the repairs necessary to correct those failures have not included engine overhaul. The lack of routine engine overhauls during ROHs and COHs indicates that the engines at entry into the overhaul did not need to be overhauled.

3.2.4 Fuel Oil Supply Pump

Each diesel engine is supplied with fuel by an attached gear-driven rotary gear pump (supported by APL 016010267). The pump was manufactured by the FMC Corporation and is rated at 4 gpm and 25 psi at 2000 rpm. As shown in Table 3-3, a total of 13 JCNs, 451 man-hours (287 man-hours reported by Ship's Force and 164 man-hours reported by IMAs), $5650 in part replacement costs, and three CASREPs were reported against problems associated with the pump.

A review of the MDS transaction narratives showed that five of the 13 JCNs submitted against the pump reported either shaft failure or drive gear failure. One of the failures was reported in two separate JCNs reported by the same ship. Apparently Ship's Force thought the failure was corrected, so the JCN closing cards were submitted. However, the failure was not corrected, and a new JCN was initiated. The other eight JCNs reported maintenance to fix leaks, excessive clearance, or testing. Other than the drive gear and shaft failures, there were no repetitive failure modes identified by these eight JCNs. The drive gear and shaft failures represented 154 man-hours or 34 percent of the total man-hour burden reported against the pump. A total of 153 man-hours was reported in two JCNs that described excessive clearances. It is concluded from these data and the small number of CASREPs submitted that the burden reported against the fuel oil supply pump did not represent repetitive failures that seriously degraded system capabilities. It is also concluded that the fuel oil supply pumps, in general, operated reliably throughout the data period.

3.2.5 Recommendations

Because of the maintenance burden experienced by the diesel engines during the data period, it is anticipated that repairs to the engines will be required during Baseline Overhaul to ensure reliable engine operation throughout an extended operating cycle. However, as discussed above, there are no major maintenance problems with the engines. MDS narrative and CASREP data did not show any dominent failure modes; therefore, except for the tests recommended for the fuel injection nozzles, no specific engine repairs can be recommended for Baseline Overhaul.

The criticality of the diesel engines to the Emergency Diesel Generating System is high, as is the criticality of the system to the ship. Because of this criticality and to provide a maximum probability that emergency diesel generators will not fail during ship deployments, COMNAVSURFLANTINST 9000.1 and COMNAVSURFPACINST 4700.1 specify predeployment and preoverhaul diesel generator inspections. These inspections are thorough, comprehensive evaluations of operating logs, previous inspection reports, and lube oil analysis (spectrometric) results, in addition to physical inspections of the diesel generators. The inspections must be performed by certified diesel inspectors. Partial teardowns occur on the basis of the diesel inspectors' evaluation of the logs, inspection reports, etc. After completion of an inspection, the diesel inspector recommends the specific repairs that should be performed to restore engine condition to acceptable levels. Therefore, before Baseline Overhaul and the follow-on Regular Overhaul the diesel engines should be inspected by a certified diesel inspector to identify the repairs that are necessary to ensure reliable operation during an extended operating cycle.

The DDEOC Repair Requirements for BOH (DDG-37 Class), dated February 1977, a document that defines mandatory Baseline Overhaul repairs, specifies that the engine governors be given a Class B overhaul during Baseline Overhaul. On the basis of data reviewed during the analysis, it is concluded that this requirement is not justified. Governor condition will be deter-

mined during the preoverhaul diesel inspection, and any necessary repairs defined by the diesel inspector. Therefore, the requirement for a Class B overhaul should be deleted from the DDEOC Repair Requirements for BOH (DDG-37 Class) document. All ships not previously implementing the MEASURE program should do so during Baseline Overhaul. The fuel injection nozzles should be removed, sent to an IMA, tested for popping pressure and spray pattern, and re-installed or replaced as necessary during Baseline Overhaul. A note should be added to MIPs A-2/114-87 and A-2/078-27 to have the fuel injector nozzles sent to an IMA for testing *if* the fuel injection nozzle tester is not installed on the ship.

3.3 SALT WATER BOOSTER PUMPS (APLs 016060106 and 016060108)

Each diesel engine on a DDG-37 Class ship is cooled by a coolant flowing through the engine. This coolant is passed through a heat exchanger where it gives up its heat to salt water. The salt water pumped through the heat exchanger is supplied by a salt water booster pump. Two different pumps are installed on DDG-37 Class ships, one for the forward engine and one for the aft engine. The forward pump (APL 016060108) is a single-stage centrifugal pump manufactured by the Weil Pump Company. It is rated at 150 gpm at 25 psi while turning at 3500 rpm. The aft pump (APL 016060106) also is a single-stage centrifugal pump manufactured by the Weil Pump Company, but its ratings of 150 gpm and 25 psi are obtained at 1715 rpm. Both pumps are close-coupled to their driving motors. None of the internal parts are common to both pumps. The aft pump operates at a slower speed than the forward engine pump because its driving motor also drives a vacuum priming pump. That pump is rated at 1750 rpm. The forward pump does not require a vacuum priming pump because its location is low enough in the ship to have an adequate gravity head.

3.3.1 Discussion

A review of the MDS data showed that the forward pump experienced a total of 22 JCNs, 121 Ship's Force man-hours, 53 IMA man-hours, and $2,421 in part replacement costs. No CASREPs were submitted against this pump, and no routine overhauls were accomplished during ship overhauls.

The aft pump experienced a total of 33 JCNs, 283 Ship's Force man-hours, 249 IMA man-hours, and $4,667 in part replacement costs. The man-hour burden averaged nine man-hours per pump per operating year. No CASREPs were submitted against this pump either, and no routine overhauls were accomplished during ship overhauls.

The man-hour burdens for both pumps were small when compared to the diesel engines and represented only a small portion of the total system maintenance burden. Based on a review of the MDS transaction narratives, it is concluded that the majority of the man-hours were expended in repairs or replacements of the internal wearing parts. Table 3-2 shows that of the parts that met or exceeded the screening criteria, only wearing parts such as shaft sleeves, wearing rings, and the thrust bushing had ratios of replacement to total population that exceeded 50 percent. The forward pump

(APL 016060108) experienced slightly higher part usage than the aft pump (APL 016060106); however, the usage rate of all wearing parts is low when compared to the total operating time in the data period experienced by the DDG-37 Class ships (58.8 ship operating years). It is concluded that this usage is not significant because repair of the pumps is within Ship's Force capability and repairs can be made in less than one day.

The salt water booster pumps operate only when the diesel engines operate and accrue little operating time. Both pumps on a ship operate about the same amount of time. The PMS for these pumps specifies a cyclic inspection of the internal parts. On the basis of the limited time the diesel engines and the pumps operate and the historical average time between part replacements, it is concluded that inspecting the salt water booster pumps once each cycle is as frequent as necessary to ensure adequate pump material condition and performance.

Discussions with Ship's Force disclosed no maintenance problems with either pump and that Ship's Force can make any repairs necessary to keep the pumps operating. Repairs to the aft booster pump are more complicated and time-consuming than for the forward pump because the aft pump has a more complex installation. This difference in burden can be seen by comparing the average man-hour burden per JCN, which was 7.9 for the forward pump (APL 016060108) and 16.1 for the aft pump (APL 016060106). The aft booster pump and its associated priming pump must both be disassembled to allow removal of their common shaft and to allow replacement of wearing parts. The aft booster pump and the priming pump are driven from opposite ends of the same motor and are attached to the same shaft. It is concluded that the difference in experienced maintenance burden is the result of the differences in complexity between the pump installations and not because of differences in wear rate.

These pumps perform a critical function for the Emergency Diesel Generating System. However, the low maintenance burdens reported against the pumps and the total lack of CASREPs submitted against the pumps indicate that few pump failures have occurred and that the failures that have occurred have not seriously degraded system capabilities. In addition, these pumps are not routinely overhauled at depot availabilities. Ship's Forces have demonstrated the capability to repair these pumps. That experience leads to the conclusion that Class B overhauls of these pumps during the Baseline Overhaul and routine, scheduled pump overhauls (to be accomplished during an extended operating cycle) are not warranted. Specific repairs to these pumps that should be completed before a ship enters an extended operating cycle should be performed by Ship's Force personnel or IMAs, as necessary, and should be determined by each ship's CSMP (Current Ship's Maintenance Project) and the cyclic PMS inspection of the internal parts.

3.3.2 Recommendations

The salt water booster pumps should be repaired during the Baseline Overhaul and the follow-on Regular Overhaul as shown to be necessary by each ship's CSMP and the results of the cyclic PMS inspection. The repairs should be accomplished by Ship's Force or IMA.

3.4 SALT WATER BOOSTER PUMP MOTORS (APLs 174750587 AND 174750604)

3.4.1 Background

Each salt water booster pump is driven by a Reliance Electric Company motor. The aft pump, located in the number 2 pump room, is driven by a 7.5 hp, 440 Vac motor that rotates at 1715 rpm. It drives a vacuum priming pump in addition to the salt water booster pump. The forward pump, located in the number 1 pump room, is driven by a 5 hp, 440 Vac motor that rotates at 3500 rpm. It drives only the salt water booster pump.

3.4.2 Discussion

The MDS and CASREP data showed evidence of little maintenance expended on the aft motor (APL 174750587) during the data period. Three JCNs were submitted against the motor for a total of 90 man-hours. No CASREPs were submitted against the motor. From these data, it is concluded that the aft motor has operated reliably and has not been a maintenance problem. It is also concluded that the motor will continue to operate reliably throughout an extended operating cycle. The motor should be repaired during Baseline Overhaul only as shown to be necessary by each ship's CSMP or POT&I results.

The forward motor (APL 174750604) has not operated as reliably as the aft motor, but has not experienced a significantly high maintenance burden. A total of 15 JCNs, 108 Ship's Force man-hours, 105 IMA man-hours, and $202 in part replacement costs were reported against this motor. The parts costs were the result of bearing replacements. Three CASREPs were submitted against this motor, all for failures that required dipping and baking the motor rotor. Of the 15 JCNs submitted against the motor, one did not report a failure mode, one reported bearing failure, six were part-only actions (no labor hours were reported) in which bearings were ordered, and seven reported either shorted or burned out windings (two of these failures resulted from flooding of the pump room, and a third was caused by failure of the associated pump. In this failure, something caused the pump to bind, which caused the rotor to overheat and melt the winding insulation). Thus, seven of the 15 JCNs (47 percent) reported against the motor involved dipping and baking of the motor rotor or rotor rewinding. Neither of these repairs can be accomplished by Ship's Force; they must be accomplished by an IMA or a depot facility.

The MDS part usage data showed a high percentage of bearing replacements when compared to total bearing population. It could be inferred from these data that these motors were experiencing bearing problems. However, a review of the MDS transaction narratives showed that this was unlikely. First, the number of bearings ordered in a maintenance action was often higher than the number of bearings required to make repairs. Ship's Force personnel were probably obtaining extra spare bearings. Second, none of the extra bearings ordered are listed as allowable spares on the motor APL, nor are they listed as suitable substitutes for the allowable spares. This indicates that the extra bearings ordered were not for the booster pump motor. Therefore, some of the bearings charged against this motor were probably for other motors. These factors lead to the conclusion that the bearing usage reported against the motor does not indicate a bearing wear-out problem.

The difference in maintenance experience between the two pump motors is probably the result of differences in motor environment. The aft motor is located at or above the water line away from the bilges and therefore operates in a relatively dry environment. In contrast, the forward pump is located below the water line and as a result, operates in a more humid environment than the aft pump. Because of the higher humidity environment experienced by the forward motor, it is not unreasonable to expect more winding-related problems for the forward motor than for the aft motor. However, as shown above, the winding-related problems experienced by the forward pump have not resulted in a significant maintenance burden or in serious, repetitive degradation of system capabilities. Any motor repairs that may be necessary during overhauls can be identified by a POT&I and each ship's CSMP.

3.4.3 Recommendations

Both the forward (APL 174750604) and aft (APL 174750587) salt water booster pump motors should be subjected to a POT&I before the Baseline and follow-on Regular Overhauls and repaired on the basis of results of the inspections and each ship's CSMP.

3.5 GENERATOR (APL 162500162)

3.5.1 Background

Each DDG-37 Class ship has two General Electric Model 31G927 450 V, 300 kW, ac generators installed in separate generator rooms. The generator is a single-bearing, open machine of dripproof-protected construction. The generator rotor is supported at the collector end by a sleeve bearing and a pedestal. The generator is attached directly to a diesel engine and is mounted on the same base with the engine.

3.5.2 Discussion

The generator experienced a low reported maintenance burden that totaled 37 JCNs, 205 Ship's Force man-hours, 103 IMA man-hours, and $973 in part replacement costs. The man-hour burden averaged only 2.6 man-hours per generator per operating year. Only one CASREP was submitted against the generator, and it was the result of an accidental flooding of the generator space rather than a component maintenance problem. The DDG-37 Class Repair Profile showed that minor repairs such as cleaning and polishing commutators and slip rings, cleaning and adjusting brush rigging, and replacing brushes and bearings (if necessary) were accomplished in two of the four SARPs reviewed. Only one part, the brushes, experienced sufficient usage to merit analysis according to the screening criteria. Although 47 brushes were replaced, representing about 60 percent of the total brush population, the usage of brushes is not considered to represent a maintenance problem because replacement of generator brushes is within Ship's Force capability, the required parts are stocked onboard, and the brushes can be replaced within a few hours. Overall, the generator has not experienced a large man-hour

burden, has not experienced repetitive part replacements or CASREPs, and has not been routinely overhauled during ROHs. In addition, Ship's Force and DDG-37 Type Desk personnel reported no generator maintenance problems. Therefore, the generator should be repaired during the Baseline Overhaul and the follow-on ROH as determined to be necessary by POT&I. At those times, as a good engineering practice, the commutators and slip rings should be cleaned and the brush rigging cleaned and adjusted. The brushes and bearings should only be replaced as necessary. Because of the low maintenance burden and lack of significant CASREPs, scheduled replacement or repairs of generator parts are not required during the operating cycle.

3.5.3 Recommendations

The generator should be repaired during the Baseline Overhaul and the follow-on Regular Overhaul as determined to be necessary by POT&I. As a minimum, the commutators and slip rings should be cleaned and the brush rigging cleaned and adjusted.

3.6 MAINTENANCE STRATEGY

3.6.1 Introduction

The current maintenance strategy of the Emergency Diesel Generating System is based on two major sources. First, the PMS details the day-to-day maintenance to be accomplished by Ship's Force. Second, the COMNAVSURFLANT and COMNAVSURFPAC maintenance manuals define a general maintenance strategy for diesel engines and specify engine inspection requirements. These elements, their inter-relationships, and the results of this analysis define the maintenance strategy for the Emergency Diesel Generating System.

3.6.2 PMS

A collection of Maintenance Index Pages, most of which have been updated within the last two years, are specified for the individual components of the Emergency Diesel Generating System (see Appendix C for a list of the specific MIPs applicable to this system). The latest update of the Emergency Generator Diesel Engine MIPs reflects increased reliance on "on-condition" or "situational requirement" maintenance actions; that is, maintenance that is accomplished only when some specified condition or performance limit (e.g., engine operating hours or compression pressure) is reached. Some maintenance requirements are to be performed either on a schedule or "on-condition". An analysis of the PMS requirements determined that they are comprehensive, practical, and should be adequate to maintain the system, in combination with the COMNAVSURFLANTINST and COMNAVSURFPACINST inspection requirements for an entire extended operating cycle. To ensure that all Emergency Diesel Generating Systems are maintained according to these requirements, during Baseline Overhaul all ships should be supplied with copies of the most current revisions of the MIPs and MRCs listed in Appendix C.

3.6.3 Maintenance Manuals

COMNAVSURFLANTINST 9000.1 and COMNAVSURFPACINST 4700.1 are maintenance manuals that define a general maintenance strategy for diesel engines and specify diesel engine inspection requirements. The general maintenance strategy specified in those documents parallels the PMS emphasis on an "on condition" strategy. Both documents stress graphic displays of trends derived from operating log readings to present a visual picture of the condition of a diesel engine. The trends of the various operating parameters (e.g., compression pressures, crankcase pressure, exhaust gas temperature) can be excellent indicators of engine condition.

Each manual specifies that the diesel engines are to be inspected at certain prescribed times. Each states that a certified diesel inspector is to inspect the emergency diesel engines at the following times:

" (1) When trend analysis supported by other factors indicates the need for overhaul.

(2) When major malfunctions are suspected.

(3) Annually if not otherwise conducted.

(4) Pre-light-off after major repairs.

(5) Pre-deployment.

(6) Pre-overhaul."*

Each inspection is composed of three phases: (1) review of records, (2) operating inspection, and (3) secured inspection. Phases 1 and 2 must be completed; Phase 3 (secured inspection, or disassembly of specific areas) may be waived in part or totally by the diesel inspector on the basis of results of the other two phases.

In addition to the inspections, both manuals specify the use of spectrometric lube oil analysis, which is an analysis of the chemical composition of the lube oil, and physical lube oil analysis, which is a determination of the change in physical properties of the lube oil over time. The Navy has established the Navy Oil Analysis Program (NOAP) to physically and spectrometrically test lube oil from many different ship components (including diesel engines), record and trend the results of those tests, and identify and prevent (whenever possible) potential engine failures. The NOAP works in conjunction with PMS, as Ship's Force is required to obtain and submit lube oil samples from both engines each quarter. NOAP personnel at the Charleston Naval Shipyard (where the SURFLANT NOAP is based) report that certified diesel inspectors commonly request historical results of lube oil tests as part of the predeployment inspections. NOAP personnel said that

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*COMNAVSURFLANTINST 9000.1, Change 4, Section 9233.1, p. 9233-1, 5 August 1977; not revised by Change 5, issued 27 February 1978.

there has been good correlation between test results and identification (and prevention) of failures across all types of equipment that are part of the NOAP. The Program is successful and is a major element of the Emergency Diesel Generating System maintenance strategy.

3.6.4 Recommendations

It is recommended that the current diesel engine maintenance strategy be retained for ships entering the DDEOC program. That is, it is recommended that the combination of PMS requirements (both calendar-time and "on condition" requirements as specified in the MIPs and MRCs listed in Appendix C) and the COMNAVSURFLANT and COMNAVSURFPAC maintenance manual requirements be used in their latest versions to maintain the Emergency Diesel Generating System throughout the extended operating cycles. The latest revisions of these documents should be provided to all DDG-37 Class ships.

CHAPTER FOUR

CONCLUSIONS AND RECOMMENDATIONS

This chapter summarizes the conclusions and recommendations resulting from the Review of Experience of the DDG-37 Class Emergency Diesel Generating System.

4.1 CONCLUSIONS

The following significant conclusions resulted from this Review of Experience:

- Although a large corrective maintenance burden was reported against the Emergency Diesel Generating System, the burden does not represent any repetitive maintenance problems.
- Routine overhauls of Emergency Diesel Generating System components are not necessary and will not be required during Baseline Overhaul or the follow-on Regular Overhaul, except as required by inspection.
- The current maintenance strategy, a combination of scheduled and "on-condition" maintenance requirements and required inspections, is adequate to maintain the Emergency Diesel Generating System throughout an extended operating cycle.
- It was determined by this analysis that a Class B overhaul of the Woodward governor, as specified by the DDEOC Repair Requirements for Baseline Overhaul, is not justified. Any necessary governor repairs will be identified during the pre-Baseline Overhaul diesel inspection.

4.2 RECOMMENDATIONS

Actions and planning activities recommended by the Emergency Diesel Generating System Review of Experience are categorized as follows:

- Baseline Overhaul Requirements
- Follow-on Regular Overhaul Requirements
- PMS Changes

No recommendations regarding intra-cycle maintenance requirements, reliability and maintainability improvements, IMA improvements, depot-level improvements or integrated logistics support improvements resulted from this analysis.

Specific recommendations resulting from this Review of Experience are summarized in Table 4-1. Recommended PMS changes are listed in Appendix C, and action items based on the recommendations are listed in Appendix D.

TABLE 4-1. SUMMARY OF DDG-37 CLASS EMERGENCY DIESEL GENERATING SYSTEM ROE RECOMMENDATIONS

Component	Recommendation
Baseline and Follow-on Regular Overhaul Requirements	
Emergency Diesel Engines	A certified diesel inspector should inspect the engines in accordance with COMNAVSURFLANTINST 9000.1 or COMNAVSURFPACINST 4700.1 (as applicable) to determine the necessary repairs. If not already done, implement the MEASURE program (the automated measuring device calibration management program). The fuel injectors should be removed, sent to an IMA, tested for popping pressure and spray pattern, and re-installed or replaced as necessary.
Generator	Make repairs as shown to be necessary by a POT&I. As a minimum, clean the commutators and slip rings and clean and adjust the brush rigging.
Salt Water Booster Pumps	Repair the pumps as shown to be necessary by each ship's CSMP and the cyclic PMS inspection.
Salt Water Booster Pump Motors	Repair the motors as shown to be necessary by each ship's CSMP and POT&I results.
PMS Changes	
Emergency Diesel Engines	A note should be added to the MIPs to have the ships that have no fuel injector tester installed send the fuel injector nozzles to an IMA for test according to the schedule specified for the test MRC.
No recommendations regarding intra-cycle maintenance, reliability and maintainability improvements, or IMA and depot-level improvements resulted from the analysis.	

SOURCES OF INFORMATION

The specific sources of information used as the basis for the Review of Experience of the Emergency Diesel Generating System are listed below:

1. Generation IV MDS part and maintenance data for the DDG-37 Class, 1 January 1970 through 30 September 1977.
2. CASREP data for the DDG-37 Class, 1 July 1973 through 30 September 1977.
3. Trip Reports (dated 30 May and 8, 9, and 12 June, 1978); ARINC Research visits to NAVSEC Code 6146, the USS Mahan (DDG-42), the USS Pratt (DDG-44), the Navy Oil Analysis Program (Code 134 at Charleston Naval Shipyard), NAVSEC (NORDIV) Code 6603, and to the DDG-37 Type Desk (COMNAVSURFLANT Code N4121A).
4. Technical Manuals as listed (all NAVSHIPS):
   a. 361-1660, Volumes I and II; 300 kw Emergency Diesel Generating Set.
   b. 341-5041; American Bosch Fuel Injection Equipment Maintenance Manual.
   c. 361-1415; Parts Book for Model 38F5-1/4 Diesel Engine Generating Set.
   d. 0363-064-5000; Starting Motor.
5. Maintenance Index Pages and Maintenance Requirement Cards for the Emergency Diesel Generating System.
6. Type Commanders' COSAL, SURFLANT (19 May 1975) and SURFPAC (19 August 1975).
7. COMNAVSURFLANTINST 9000.1, NAVSURFLANT Maintenance Manual, 12 June 1975, through Change 5, dated 27 Feburary 1978.
8. COMNAVSURFPACINST 4700.1, COMNAVSURFPAC Ship and Craft Material Maintenance Manual, Volume I, 6 June 1975.
9. DDG-37 Repair Profile, dated June 1977, prepared by PERA (CRUDES).
10. DDEOC Repair Requirements for BOH (DDG-37 Class), February 1977.
11. Baseline SARP for Baseline Overhaul of DDG-37 Class, prepared by PERA (CRUDES) for NAVSEA 934, June 1977.
12. Ship Information Book for USS Coontz, Volume 2, March 1972, NAVSHIPS 0905-475-4020.

APPENDIX A

EMERGENCY DIESEL GENERATING SYSTEM BOUNDARIES

The Emergency Diesel Generating System discussed in this report consists of the major components and test kits listed in Table A-1, which presents component nomenclatures, component APL numbers, and APL quantities per ship as derived from the Type Commanders' COSAL. In the development of this table, an attempt was made to resolve inconsistencies among Type Commanders' COSAL and MDS data, but all such inconsistencies could not be resolved. This configuration is the best estimate from all available data sources. A schematic diagram of the system is presented in Figure A-1.

TABLE A-1. Major Components of the DDG-37 Class Emergency Diesel Generating System

Nomenclature	EIC	APL/CID	Quantity by Hull Number									
			DDG-37	DDG-38	DDG-39	DDG-40	DDG-41	DDG-42	DDG-43	DDG-44	DDG-45	DDG-46
Generator, 300 kW, 450 Vac	3301	162500162	2	2	2	2	2	2	2	2	2	2
Generator, Tach, 55 Vac		162500157	2	2	2	2	2	2	2	2	2	2
Generator, 80 Vdc, 3.6 kW		618000024	2	2	2	2	2		2	2	2	2
Starter, Motor, 36 V		154400622	2	2		2	2	2	2	2	2	2
Starter, Engine, 30/36 V		340040120	2	2	2	2	2	2	2	2	2	2
Diesel Engine, 7 Cyl., 38F5-1/4		665360181	1	2	2						2	2
Diesel Engine, 7 Cyl., 38F5-1/4		665360182				2	2	2	2	2		
Diesel Engine, 7 Cyl., 38F5-1/4		665360207	1									
Fuel Injection Pump		018960176	14	14	14	14	14	14	14	14	14	14
Fuel Injector		290010065	14	14	14	14	14	14	14	14	14	14
Hydraulic Governor		701110136									2	
Hydraulic Governor		701110194	2	2	2	2	2	2	2	2		2
Flexible Coupling		782350206	2	2	2	2	2	2	2	2	2	2
Fuel Oil Filter		480110233	2	2	2	2	2	2	2	2	2	2
Lube Oil Filter		480110244	2	2	2	2	2	2	2	2	2	2
Cooler, FD, 73.5 Sq.Ft.		030130376	2	2	2	2	2	2	2	2	2	2
Cooler, FD, 90.3 Sq.Ft.		030130377	2	2	2	2	2	2	2	2	2	2
Fuel Oil Supply Pump, 4 gpm		016010267	2	2	2	2	2	2	2	2	2	2
Tester, Cylinder Compression		384010003			1							
Tester, Fuel Injector		462030001	1	2	2	1			2		1	
Temperature Regulating Valve		882140676	2	2	2	2	2	2	2	2	2	2
Pyrometer, 0-1000°F		384520042	1		2		2	2	2		2	2
Pyrometer, 0-1000°F		384520063	1	2						2		
Pyrometer, 0-1000°F		384520069				2						
Tachometer, 100-1400 rpm		388510007		2	2	2	2	2	2	2	2	2
Tachometer, 100-1200 rpm		388510047	2									

TABLE A-1 (Continued)												
			Quantity by Hull Number									
Nomenclature	EIC	APL/CID	DDG-37	DDG-38	DDG-39	DDG-40	DDG-41	DDG-42	DDG-43	DDG-44	DDG-45	DDG-46
Cooling Water Test Kit	3301	2-870004007	1	1	1	1	1	1	1	1	1	1
Oil Condition Test Kit		2-870004025	1	1	1	1	1	1	1	1	1	1
Salt Water Booster Pump, 150 gpm		016060106	1	1	1	1	1	1	1	1	1	1
Salt Water Booster Pump, 150 gpm		016060108	1	1	1	1	1	1	1	1	1	1
Vacuum Pump		017070072	1	1	1	1	1	1	1	1	1	1
Pump Motor, 440 Vac, 7.5 hp		174750587	1	1	1	1	1	1	1	1	1	1
Pump Motor, 440 Vac, 5 hp		174750604	1	1	1	1	1	1	1	1	1	1

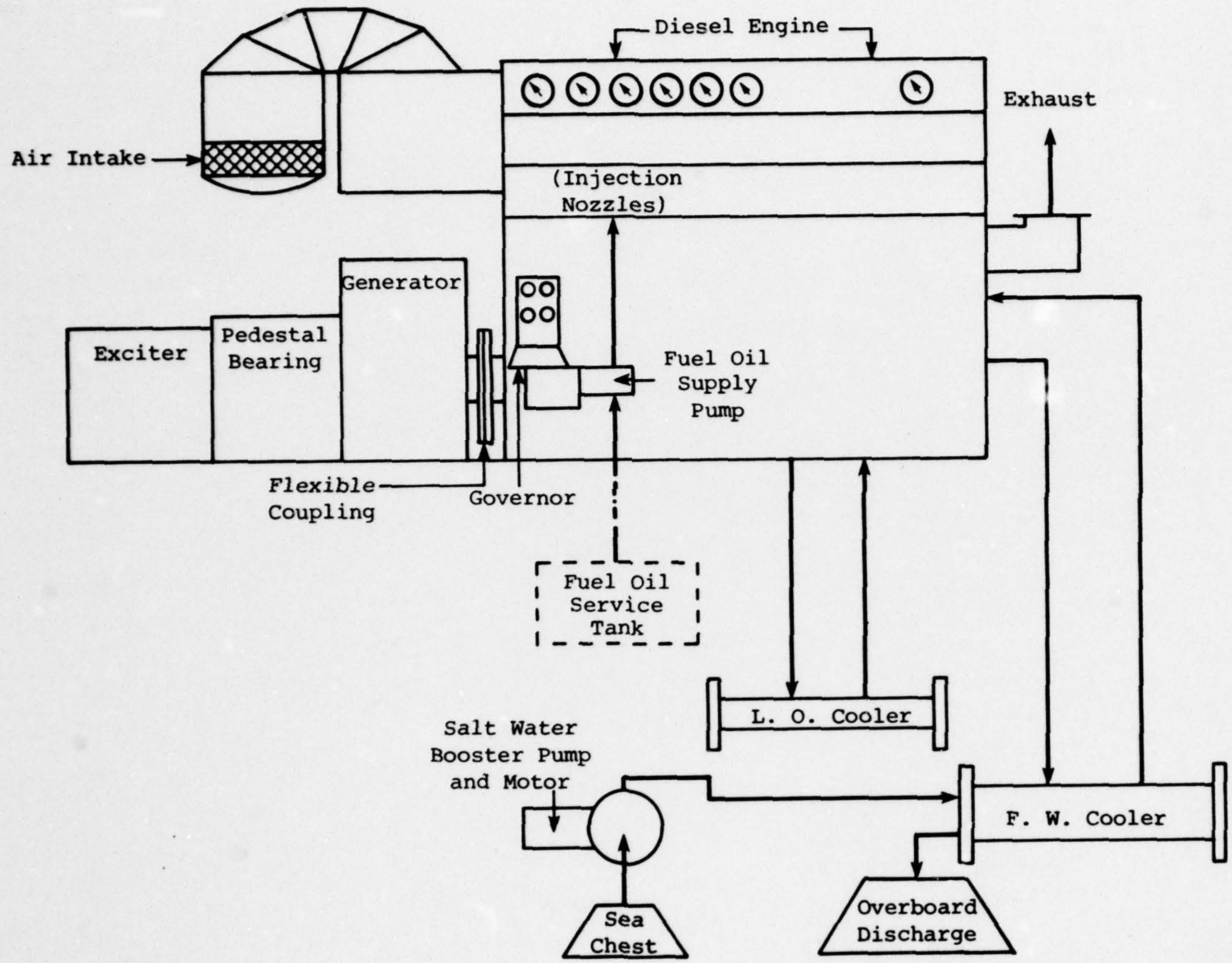

Figure A-1. SCHEMATIC DIAGRAM OF EMERGENCY DIESEL GENERATING SYSTEM

APPENDIX B

EMERGENCY DIESEL GENERATING SYSTEM CASREP SUMMARY

DDG-37 Class Emergency Diesel Generating System CASREP data for the period 1 July 1973 through 30 September 1977 were reviewed to determine the types of critical failures experienced by the system. Nineteen CASREPs were reviewed. A summary of these reports, by components and failure type, is presented in Table B-1.

TABLE B-1. CASREP SUMMARY FOR THE DDG-37 CLASS EMERGENCY DIESEL GENERATOR SYSTEM

Reason for CASREP	Number of CASREPs	Percent of Total CASREPs	Number of Ships
. Diesel Engine			
.. Pyrometers inoperative	3		
.. Fuel injectors leaking	3		
.. Piston rings worn or broken	2		
.. Fuel pump drive gear broken	2		
.. Starter motor inoperative	2		
.. Main bearings loose	1		
.. Fuel pump drive shaft sheared	1		
.. Fresh water pump inoperative	1		
Subtotal	15	78.9	7
. Generator			
.. Inoperative due to flooded space	1	5.3	1
. Salt Water Booster Pump			
.. Inoperative	3	15.8	3
Totals	19	100.0	8

APPENDIX C

MRC EVALUATION

This appendix specifies the Maintenance Index Pages applicable to the major components of the DDG-37 Emergency Diesel Generating System. In addition, the MRC Evaluation Table lists the Maintenance Requirements Cards that should be changed.

The following MIPs are applicable to the system:

COMPONENT	APL	MIP NUMBER
Diesel Engine and Major Accessories	665360181 665360182 665360207	A-2/114-87 A-2/117-87 A-2/078-27
Fuel Oil Pump	016160314	A-22/5-C4
Pyrometers	384520042 384520063 384520069	IC-39/14-55 IC-39/14-55 IC-39/14-55
Starting Batteries	1-62004456*	EL-1/15-67
Relief Valves	Various	A-701/1-37
Salt Water Booster Pump	016060106 016060108	A-19/246-75 A-19/246-75
Salt Water Booster Pump Motor	174750587 174750604	EL-4/28-67 EL-4/28-67
Motor Controllers	Various	EL-3/25-67
Generator	162500162	EL-8/79-17
Generator Bearings	None	EL-8/62-85
Interconnecting Cables	None	EL-8/58-56

*Allowance Equipage List Number

The column headings of the DDEOC MRC Evaluation form are explained as follows:

- MRC Title - Description of maintenance specified by MRC
- MRC Number - Identification number of MRC
- Current Status (self-explanatory)
- Man-hours - Personnel time burden allotted to complete maintenance action
- Periodicity - When the MRC maintenance action is to be performed e.g., D = Daily, W = Weekly, M = Monthly, Q = Quarterly, C = Once every cycle, R = As required, etc.
- Type - Perform maintenance (P), or survey material condition of component (S)
- Maintenance Level - Maintenance action to be performed by tender, DDEOC Site Team, or Ship's Force
- Where Performed (self-explanatory)
- Data Recorded - Indicates whether data are recorded during performance of maintenance action

DDEOC MRC EV

MRC TITLE	MRC NUMBER	CURRENT STATUS		MAN-HOURS ALLOWED		PERIODICITY	
		OLD WITH REVISION	NEW	PRE-DDEOC M/H	POST-DDEOC M/H	PRE-DDEOC	POST-
Test fuel injection nozzles	84-2EWA-Y	X		6.0	6.0	A-R	A
Test fuel injection nozzles	B3-1SYZ-Y	X		6.0	6.0	A-R	A

*P = PERFORM MAINTENANCE; S = SURVEY INSPECTION
**MAINTENANCE LEVEL = SHIP'S FORCE, IMA, DEPOT, ETC.

C MRC EVALUATION

SHIP CLASS: DDG-37
SMA NO: 37-208-312
SYSTEM: Emer. Dsl. Gen.

PERIODICITY		TYPE*	MAINTENANCE LEVEL**	WHERE PERFORMED	DATA RECORDED	REMARKS
PRE-DDEOC	POST-DDEOC	P–PERF. S–SURV.		I–IN PORT S–AT SEA	YES NO	
A-R	A-R	S,P	Ship's Force and IMA	I	No	Add to MIP "For ships with no tester installed, send fuel injector nozzles to an IMA for test." (MIP A-2/114-87)
A-R	A-R	S,P	Ship's Force and IMA	I	No	Add to MIP: "For ships with no tester installed, send fuel injector nozzles to an IMA for test." (MIP A-2/078-27)

APPENDIX D

DDEOC ACTION TABLE

DDEOC action items are presented in the table of this appendix. The format of the table is arranged to display the status of changes being implemented through completion of the Class Maintenance Plan and to serve as a ready reference to specific paragraphs in Chapter Three that address in detail the problems involved.

DDEOC ACTION

1. ACTION ITEM * a. NO.	b. TITLE	2. DDEOC EVALUATION **	3. ACTION ITEM DESCRIPTION	4. REPORT REFERENCE (PARA.)	5.
I	Baseline Overhaul Requirements and follow-on Regular Overhaul Requirements		Emergency Diesel Engines: Inspect (certified diesel inspector) in accordance with COMNAVSURFLANTINST 9000.1 or CONNAVSURFPACINST 4700.1 (as applicable) to determine the necessary repairs; implement the MEASURE program; remove the fuel injector nozzles, send them to an IMA, test them for popping pressure and spray pattern, and reinstall or replace as necessary.	3-2	
			Salt Water Booster Pumps: Repair pumps as shown to be necessary by each ship's CSMP and the cyclic PMS inspection.	3.3	
			Salt Water Booster Pump Motors: Repair the pumps as shown to be necessary by POT&I and each ship's CSMP.	3.4	
			Generator: Perform a POT&I and make repairs as indicated by the results. As a minimum, clean the commutators and slip rings and clean and adjust the brush rigging.	3.5	
II	PMS CHANGES		Emergency Diesel Engines: Add a note to the MIPs to read "For ships with no tester installed, send the fuel injector nozzles to an IMA for test."	3.2	

* NOTE 1: DEVELOPING ACTIVITY FILL IN THE FOLLOWING BLOCKS: 1a, b; 3; 4; 5 (IF KNOWN); 6a, IF REQUIRED FOR CONTINUA

** NOTE 2: DDEOC EVALUATION – APPROVED, FURTHER STUDY REQ'D, ETC.

† NOTE 3: RESPONSIBILITY – ACTIVITY RESPONSIBLE FOR TAKING THE ACTION.

/

SHIP CLASS: DDG-37

SMA NO: 37-208-312

SYSTEM: Emer. Dsl. Gen.

DDEOC ACTION TABLE

	4. REPORT REFERENCE (PARA.)	5. RESPONSIBILITY †	6. SCHEDULING DATES			7. REMARKS, FUNDING IMPLICATIONS, ETC.	8. ACTUAL ACTION TAKEN
			a. REQD.	b. START	c. COMP.		
: (certi- ince with AVSURF- deter- ment uel IMA, d spray as	3-2	NAVSEA/TYCOM					
pumps as 's CSMP	3.3	NAVSEA/TYCOM					
pair the POT&I	3.4	NAVSEA/TYCOM					
e s. As nd e brush	3.5	NAVSEA/TYCOM					
te to tester nozzles	3.2	NAVSEA				MIP A-2/114-87 (MRC 84-2EWA-Y) and MIP A-2/78-27 (MRC B3-1SYZ-Y)	

UIRED FOR CONTINUATION OF DEVELOPING ACTIVITY TASK; 7, AS NECESSARY.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The gola of the Destryer Engineered Operating Cycle (DDEOC) Program is to effect an early improvement in the materail eondition of ships, at an acceptable cost, while maintaining or increasing their opeartional availability during an extended opeating cycle. In support of this goal, System Maintanance Analyses (SMAs) are being conducted for selected systems and subsystems fo designated surface combants. The principal element of an SMA is the Review fo Experience (ROE) This report documents the ROE for the DDG-37 (over)

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